Jacobi (Mary Putnam.)

REMARKS UPON EMPYEMA.

BY

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REMARKS UPON EMPYEMA.[1]

BY MARY PUTNAM JACOBI, M.D.,
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I DO not propose to enter into an exhaustive statistical discussion in regard to empyema or its treatment. This ground was largely, though not completely, covered in a discussion held at the New York Academy of Medicine, in the winter of 1887, in which several physicians and surgeons took part. I may add that this discussion yielded more positive and useful conclusions in regard to the treatment of empyema than were reached by the discussion of the International Congress at London, in 1881. In six years, a most substantial progress had been effected.

The physiological problems involved in empyema have been discussed theoretically and experimentally, as recently as last September, at the first meeting of the American Pædiatric Society, held in Washington. This discussion was sustained by Drs. O'Dwyer and Northrup, and the President of the Society, all from this city.

It might easily seem, therefore, that nothing re-

[1] Read before the New York Academy of Medicine, Section on Pædiatrics, November, 1889.

mained at present to be said upon the subject. Nevertheless, as various considerations have suggested themselves to me during observations of the case I am about to relate, I take the liberty of laying them before the profession.

A little boy, four years of age, was brought to my office in September, with a history of five weeks' febrile sickness, which had been considered by one physician to be a malarial fever; by another, typhoid. For some time the fever had been of a hectic type, coming on only in the afternoon. On the occasion of the first visit, which was in the morning, the temperature was normal. The child was excessively pale, with a suggestion of œdema in the face, but not elsewhere. The respiration was not accelerated, and cough had been so slight as not to be mentioned by the mother until after I had inquired concerning it. Inspection of the chest, however, at once suggested thoracic trouble, for the anterior portion was markedly arched forward, the arching being equally prominent over the left side and over the sternum, and not much less over the right side. The mother had noticed that the chest was—as she expressed it—swollen. There was some dilatation of the veins over the sternum. On the left side, absolute percussion dulness extended from the second rib over the whole anterior region of the chest and reached the right border of the sternum. Above this zone of absolute dulness, a zone of relative dulness extended to the apex. Posteriorly, dulness extended from the spine of the scapula to the base of the lung. Over the

region of absolute dulness, breath sounds were entirely absent. There was no tubular breathing. From the age and fretfulness of the child, it was impossible to obtain whispering pectoriloquy—which is said to be present in serous effusion, absent in empyema, and to constitute a valuable means of diagnosis between them. Above the region of absolute dulness, on the left side, both before and behind, existed tubular breathing; right lung was normal. The apex of the heart pulsated in the epigastrium.

I regret that cytometer measurements of the chest were not made at this time. Nor was it noticed whether the liver was displaced, through compression and compensatory longitudinal enlargement of the right lung.

The assemblage of signs and symptoms just enumerated sufficed to justify an almost positive diagnosis of a purulent effusion in the left pleura, sufficiently abundant to displace the mediastinum considerably to the right side. An exploratory aspiration was deferred until the moment for operation, which was appointed for the afternoon of the same day. At this time the hypodermic needle, inserted painlessly after previous application of ice and salt, withdrew a syringeful of pus.

In saying that anterior mediastinum was displaced, I have used the current expression, but have not used it in regard to the heart, which was found beating in the epigastrium, and which would usually be said to be pushed over. According to the argu-

ments and demonstrations of Douglas Powell,[1] of London, Peyrot,[2] of Paris, and Garland,[3] of Boston, the displacement of the heart in pleural effusion is not due to pressure of the fluid on the diseased side, but to aspiration of the lung on the sound side of the chest. "The mediastinum," observed Dr. Powell in 1869, "is poised by the contending elasticities of the two lungs." The lungs exercise a traction power on the mediastinum, and also on the thoracic walls. The latter have been shown by an experiment of Dr. Salter's, repeated by Dr. Powell, to move outward about $\frac{1}{100}$ of an inch when air was admitted into the pleural cavity after death. This shows that during life, and while the lungs were expanded, they were habitually drawing the thoracic walls inward, by virtue of their elasticity. When the lungs collapsed, by the admission of air into the pleura, this traction ceased, and the thoracic walls moved outward to an extent corresponding to the previous retraction. The same degree of traction must necessarily be exerted on all parts of the pleural cavity, hence upon the mediastinal walls as well as on the thoracic. But as both lungs exercise the same pressure, each, normally, neutralizes the influence of the other, and the heart remains poised or suspended from the attachments of its great vessels, between two equal opposing forces.

If, now, the elastic traction of one lung dimin-

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[1] British Medical Journal, 1869.

[2] Archives Gén. de Méd., 1876.

[3] Boston Med. and Surg. Journ., 1878, and monograph.

ishes, the power of the other lung is proportionately increased, and the mediastinum, with the heart contained in it, is accordingly drawn to that side.

Dr. Powell points out that it is only in this way that we can explain the displacement of the heart in the presence of a very moderate degree of effusion. An important corollary to the same proposition is, that cardiac displacement is not to be held to indicate a very large amount of effusion. On the contrary, it is one of the earliest symptoms, and observable while the effusion is yet quite small.

Dr. Garland, in his most ingenious monograph on Pneumono-dynamics,[1] quotes Skoda as expressing the same opinion on the cause of cardiac displacement. Nevertheless, it is unquestionable that the majority of writers continue to speak of the displacement of the heart by pressure of the effusion.

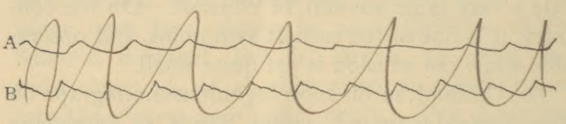
It is easy to verify by experiment Dr. Powell's statement—that cardiac displacement occurs with very small effusions, and soon after they are poured out. Indeed, in the experiment, where the effusion is necessarily sudden, the displacement is equally sudden. Thus, in an etherized dog, having ascertained that the cardiac apex was in its normal position, I injected—through a glass canula, fitting air-tight—seventy-five cubic centimetres of warm water into the left pleural cavity at the anterior axillary line, and in the seventh intercostal space. Three minutes later the heart was found to be visibly and forcibly pulsating at the right of the sternum. A respiratory

[1] Pneumono-dynamics: Boston, 1878.

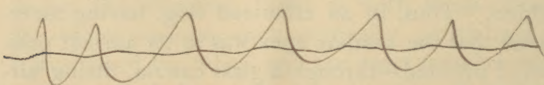
tracing taken immediately, with a tambour placed over the right side of the chest, shows a great amplification of the respiratory excursion, both in inspiration and expiration.

Tracing No. 1 contains (*A*) a normal tracing taken before any operation, and (*B*) a tracing taken immediately after plunging one arm of a fine glass T-tube into the left pleural cavity.

Chart Trace I A

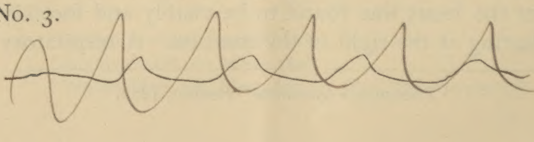


In this experiment the tissues were incised down to the internal intercostal muscles and the glass tube plunged into the pleura. The facility with which this can be done shows the rapidity with which the lung retracts with its visceral pleura, so that the virtual cavity is instantaneously converted into an actual one. Were not this the case, it would be almost impossible to open the pleura without wounding the lung. The following tracing shows

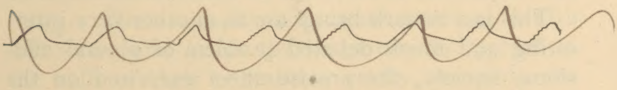


the effect on respiration of opening the pleura in the way described—the inspiration on the uninjured side becomes more ample, as is seen in tracing No. 3.

Trace I B



The fourth tracing, taken after injection of seventy-five centimetres of warm water, shows that this amplitude is still further increased. Trace II



A

As Dr. Douglas Powell remarks, the heart is so movable that its displacements may serve as a most delicate and accurate measure of any perturbation in the normal intra-thoracic equilibrium of forces—that is, of balancing tractions. It is interesting to notice that while a diminution in the elastic traction of the lung, which coincides with a pleural effusion, allows the heart to be displaced—*i. e.*, drawn over to the opposite side—diminution of elasticity due to solidification and diminution of size, as when lung tissue collapses over an empty cavern, is followed by displacement of the heart toward the affected side, so that marked lateral and upward displacement of the heart is an important sign of contraction of pulmonary caverns, and, to a considerable extent, measures their rate of progress to healing. But in this case the heart follows the negative pressure determined by the potential vacuum which exists, when the lung tissue tends to retract from the thoracic wall. When there is a pleural effusion there is no potential vacuum, for the fluid completely fills all the space left by the retracting lung, and the amount of fluid and amount of pulmonary retraction are necessarily exactly proportioned to each other. It is only in this sense that the fluid

can be said to favor directly the cardiac displacement. Its principal effect is indirect, and exerted through the lung, which, in presence of the fluid, loses a portion of its power of elastic traction.

This last remark brings me to another very interesting and much debated problem of pleural effusions, namely, the precise effect exercised on the lung by the fluid in the pleura.

The same line of thought which leads to the view that the heart is displaced by pressure, sustains the current theory that the lung is "compressed" by the effused fluid. Indeed this theory is habitually taken as a matter of course, and as not needing discussion. Nevertheless, as soon as we begin to reflect on the nature of the lungs, and of the forces which maintain them expanded in the thoracic cavity, it seems to me remarkable that the true view of the case should have remained so long undiscovered. The first demonstration of this view that I have read, was given by Dr. Garland, of Boston, in 1878, and is admiringly adopted by Dr. Douglas Powell. This view reposes upon obvious theoretical considerations; upon the results of experiments with inflated balloons in glass vessels, where the physical conditions of pleural effusions are imitated with surprising accuracy; finally, upon the results of injections into the pleural cavity of dogs made with fluids capable of solidification, and which form permanent moulds *in situ*, and thus indicate the course taken by the injection in the fluid state.

The theoretical consideration is that the lungs are

highly elastic bodies, normally maintained in a state of extreme tension by the pressure of the air contained in them, and which, while the pleural surfaces remain in contact, is counteracted by nothing. The atmospheric pressure hence acts with full force, and keeps the lungs exactly applied to the walls of their containing cavity, except in the complemental space at the base, reserved for forced inspiration. But if either air or liquid be admitted into the pleura, the internal atmospheric pressure within the pulmonary cavities, the bronchi, and air-cells, is counteracted to an exactly proportionate extent. To the same extent to which the pressure of the air is diminished, is the elastic tissue of the lung able to return from the over-stretched conditions into which it had been put by the unopposed pressure of the air. Like any other elastic body, the lung tends to return to its original size as soon as the distending force is withdrawn. In the case in question, the distending force is not withdrawn, but it is partially neutralized. To the same extent does the elasticity or retractility of the lung come into play: it retracts upon its contained air.

As in every interplay of physical forces, the effective condition of this phenomenon, the retraction of the lung, cannot be considered its efficient cause. The effusion does not precede in time the retraction; but the two phenomena march *pari passu* together. The efficient cause of the retraction of the lung is the elasticity of its tissue, which comes into play as soon as the obstacles to its manifestation are removed. The effusion removes the obstacle by

neutralizing to a greater or less extent the pressure of the air. It is, therefore, the condition upon which the manifestation of the retractile power of the lung depends; but by no means the efficient cause of the retraction or of the diminution of size.

An elastic body cannot be compressed until its elasticity is exhausted.

So long as any elasticity remains, the body exercising pressure can only neutralize atmospheric pressure, and allow the over-stretched elastic body to return upon itself. The pressure allows this; it does not compel the reduction of the body to a small size, as is done when inelastic bodies are compressed, by forcible approximation of their molecules.

This theoretical exposition is well illustrated by Garland, by means of such a little apparatus as is here shown. It consists of a pear-shaped flask, surmounted by an opening closed with a rubber cork, and terminating below in a long tube, through which passes a stop-cock. Within the flask is suspended a thin rubber balloon, attached to a glass tube, which passes air-tight through the rubber cork. The stop-cock and tube at the lower part of the flask are filled with water, by immersing the tube in water to above the level of the stop-cock, while the cork is out of the flask. The tube is then plunged under water, the stop-cock opened, the cork inserted tightly, and the balloon inflated through the glass tube until it fills the flask. If the size of the balloon and the flask corresponded accu-

rately, the balloon would adapt itself accurately to the walls of the flask. As it is, the adaptation is

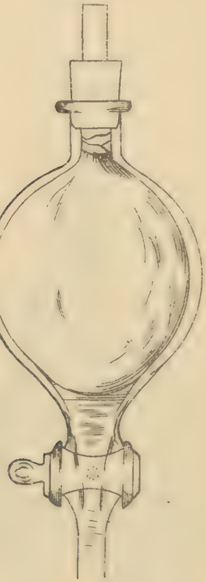
FIG. 1.

Balloon around glass rod, before insertion into flask.

exact enough to fulfil the conditions of the experiment. See Fig. 2.

The stop-cock may then be closed and the apparatus be lifted out of the water without causing any change. The balloon remains inflated, for, though its cavity communicates freely with the open air, the

FIG. 2.



Flask with balloon expanded and filling flask. Tube filled with water, and then closed.

column of water remains in the lower tube. If now, while this lower tube is plunged to a greater or less extent under water, the stop-cock be opened, the column of water in the tube will be subjected to the

pressure of the water in the vessel—pressure which increases with the depth of immersion. At a certain depth there will be no change, for the column of

FIG. 3.

Flask after some water has been admitted by turning the stopcock while nozzle under water. Balloon retreated and partly collapsed.

water below the balloon will be equal to the pressure of the atmospheric air within. If the tube be plunged lower, the pressure of the column of

water will become equivalent to a part of the pressure of the air, and will neutralize it. To exactly the same extent will the balloon be relieved of a certain degree of tension, and return upon itself proportionately. Thus, as Garland expresses it, the "balloon flees before the advancing column of water," and must continue to do so until its retractility is exhausted, and the flask is exactly filled by water plus the collapsed balloon. In this condition it would be impossible to aspire water into the flask, as had previously been done while the balloon was retracting and exerting a negative pressure upon the column of water. But if more water were injected forcibly into the full flask—as it could make no room for itself against the rigid walls—it would, with a *point d'appui* taken upon them, press upon the balloon until the compressibility as well as the elasticity of the latter was exhausted. The same thing may happen with pleural effusions, but only under one of two circumstances. The effusion may be exceptionally abundant, or the lung may have been already consolidated by disease, and thus, at the outset, deprived of its elasticity, and, therefore, exposed to compression much earlier in the course of an effusion.

Observation of this simple but instructive apparatus illustrates some other circumstances. As the balloon retracts, returning upon itself from the condition of over-distention, it becomes flaccid. It is to an analogous flaccidity of the lung that Weil has attributed the phenomenon of tympanitic percussion

resonance often heard over the lung above the level of a pleural effusion.

The stomach, whose walls are flaccid, gives a tympanitic resonance which, as every one knows, contrasts markedly with the much lower percussion note of the normally distended lung. It is easy to demonstrate experimentally, as I have myself done before a class, by inflating the excised lung of a calf or sheep, that, when inflation was complete, percussion yielded the normal tone; but if air was allowed to escape from the lung, percussion gave a tympanitic sound. According to Weil, in the distended lung the walls of the air-cells do not vibrate with the vibrations of their contained air; but in the relaxed lung, as in the stomach and intestine, the walls of cavities containing air are thrown into vibrations whenever the air vibrates; and the coincident vibrations of heterogeneous bodies result in the tympanitic sound.

Another point deserving notice in the apparatus is the reëxpansion of the balloon if water be allowed to run out through the inferior opening. The balloon reëxpands as rapidly as it had retracted. It is drawn by the negative pressure of the water potentially; the efficient cause of the reëxpansion being the pressure of the internal air, when a tendency exists to form a vacuum, as the water falls away from the balloon. This phenomenon is of great importance in understanding the reëxpansion of the lung after operations for the removal of a pleural effusion. I will return to it again. In describing the condition of the child

previous to operation, I have said that the region of absolute dulness reached the second rib in front and the spine of the scapula behind, and was bounded superiorly by a horizontal line. There did not exist the curved, or letter S line, discovered and described by Dr. Ellis, of Boston. According to this line, the region of absolute dulness is highest in the axillary line, and thence descends toward the median line, to the sternum in front, to the vertebral column behind. Dr. Peter, of Paris, interpreted this line as an indication of a purulent effusion, which, being more viscid than a serous fluid, would adhere in places to the thoracic walls, while the serous fluid would assume the hydrostatic level. It is unnecessary to discuss this theory, for it has been abundantly proved that the curved line can be distinguished by careful percussion when the effusion is serous as well as when it is purulent. But Garland, in seeking to explain the *rationale* of this elevation of the fluid in the axillary line, has ingeniously demonstrated the value of the curved line as a measure of the remaining retractility of the lung—as a measure consequently of the amount of effusion.

Since the elevation of one part of the upper surface of a mass of liquid is contrary to hydrostatic laws, it is clear that these must have been thwarted by some special force acting in opposition to them. Fluid cannot rise above its own level, and if it is found above it, it must have been driven or pushed up. Now it has already been shown, and elegantly illustrated by the balloon and flask apparatus, that during the early stages of a pleural effu-

sion, while the lung is retracting, it necessarily aspires the fluid in contact with it, by virtue of negative pressure. The force of retraction is greatest where the extension has been greatest, hence first and most powerfully exercised from below upward. Subsequently, the lung also begins to retract in its transverse diameter, or from the external thoracic wall toward the lung root. In so retracting, a virtual vacuum is created between the lung and the chest wall, and into this the fluid rises. It rises first and higher in the axillary line, because the force of retraction is greater in the transverse diameter of the lung than antero-posteriorly. Correlatively, as long as the region of absolute dulness is confined to the inferior and axillary portions of the chest, and the diaphragm is not depressed, we may infer that the effusion is moderate, and that the lung retains much retractile, hence much expansile, power. Even when absolute dulness has spread over the anterior and posterior regions of the chest, the fluid may be known to have followed the lung, so long as its upper border presents a curved line. But if the lung reaches its furthest limit of retraction, it ceases to aspire the fluid, or to hold this above its normal level, which is a horizontal line.

Contrary, therefore, to the theory of Peter, the maintenance of the curved line, incapable of distinguishing the nature of the fluid, does indicate moderation in its amount, and preservation of good retractile power in the lung; while the substitution of a straight line, indicating the natural level of the

fluid, shows that the effusion is extensive, and the lung on the point of being compressed.

Garland tested the respiratory force of the lung by means of injections, into a dog's pleura, of cocoa butter, which was allowed to remain there until complete solidification. Examination of the moulds thus formed showed that, whether the injection had been made with the dog in a horizontal position or suspended vertically, the fluid had risen above its hydrostatic level, and formed a curved line projecting toward the axilla. I have imitated this experiment and obtained similar, though less striking, results, as the amount of cocoa butter injected was smaller.

The little boy, whose case forms the text of this paper, as soon as the diagnosis of empyema had been confirmed by the hypodermic syringe, was etherized, laid upon the affected side, and an incision made in the eighth intercostal space in the posterior axillary line. The operation was rendered a little more difficult by the position given to the child. But this inconvenience was held to be compensated by the advantage of securing to the sound lung entire freedom from compression. The incision through the skin was a little less than an inch in length, and was made layer by layer until the pleura was nearly reached, when a trocar was plunged in, and its opening subsequently enlarged until it would admit a drainage-tube the size of my finger. This could just be squeezed through the space between

the ribs, which, as always in a young child, was narrow.

On account of this narrowness, which has frequently been recognized as a source of difficulty, it did not seem that anything would be gained by making a longer incision, unless, as in Dr. Cabot's method, two drainage-tubes were to be inserted.

The size of the opening which should be made in the chest, in order to evacuate a purulent effusion, has been the subject of animated controversy.

It seems scarcely necessary to reopen the discussion in regard to aspiration of the chest in empyema. The discussion of the New York Academy of Medicine, held in 1887, resulted in the unequivocal condemnation of aspiration for purulent effusion, and in the recommendation of antiseptic incision as a method which, as Dr. Holt remarked, has changed empyema in children from being one of the most fatal to one of the most amenable of diseases. But it is both interesting and surprising to note how very recently this method has been definitely acquired. Guibert, in 1875,[1] relates with complacency the case of a boy of eleven, under treatment for nine months, and subjected to seventy-four punctures with Dieulafoy's aspirator. In 1862 Ziemssen, quoted by Schenks, said that operation was rarely needed for empyema in children. In the great majority of cases in which aspiration has been tried, the continued recurrence and aggravation of all morbid conditions decided the phy-

[1] Lyon Médical, November, 1875, quoted by Bouveret.

sicians to resort to incision, with drainage. Dr. Holt has collected 121 cases treated by aspiration, of which 6 died; 23, or nineteen per cent., were cured; the rest came to treatment by incision. Yet in the International Congress of 1881, although Ranke and Gerhardt advocated free incision, Baginsky advised delay, to see if the pus might not be removed by expectoration. Robert Lee and Parker, of London, advocated repeated aspiration, and Dr. Jacobi reported three cases of empyema in children, observed in one year, who had been radically cured by aspiration.[1]

[1] Esch, N. Y. Med. Record, 1887, relates a case of empyema in a boy eight years old. Twelve ounces of pus were withdrawn from the pleura by aspiration, and, after a temporary improvement, the refilling of the chest necessitated repetition of the aspiration seven times in the course of a few weeks. Each time, eight to fourteen ounces of pus were withdrawn. The child had chills, and a temperature ranging from 102° to 104°. Finally, Esch injected through the aspirating needle eight ounces of a two per cent. solution of biborate of soda, and withdrew in ten minutes. Speedy recovery.

Leichtenstern, in Gerhardt's Cyclopædia, says that it is unquestionable that empyema *may* be cured by repeated puncture and aspiration, like any other abscess. In 1871, Bouchert (Gaz. des Hôp., 1871) proposed to treat infantile empyema exclusively by this method.

Branthomme's thesis contains eighteen cases cured by single aspiration.

Bouveret quotes forty-three from the thesis of Branthomme, divided into four groups. In the first group of 18 cases, a single aspiration sufficed to cure. In the second group of 11 cases, the aspiration was practised twice—the recovery equally prompt. In the third group of 3 cases, there were three aspirations, and speedy recovery. Finally, in a fourth group of 11 cases the number of aspirations ranged from 6 to 122.

Some years ago I treated by aspiration a case of empyema in a child of eighteen months, and the child died.[1] The dangers of aspiration are not purely negative and dependent on delay in relieving the organism of its collection of pus, and lungs and heart of the mechanical impediments offered to their functions; but, unless the disinfection of the aspirating needle is perfect, and it often is not, there is the same danger in plunging it into a closed pleural effusion as has been so often noted in the hypodermic exploration or aspiration of abdominal cysts, and of which I have myself reported two observations. If germs are carried into a cavity with a free opening, and from which a current of fluid is constantly flowing, they have at least a large proportion of chances of being washed away. But, introduced into an hermetically closed cavity, no such chance is offered, and infection is unavoidable. This danger does not seem to have been emphasized by authorities as distinctly as the fact of the almost inevitable recurrence of the effusion after the most complete aspiration, and the great probability that the aspiration in every case must remain incomplete. Other more exceptional dangers of aspiration, empyema shares in common with serous effusions; the dangers of albuminous expectoration, pulmonary

[1] Schenker (Jahrb. für kinderheilk., N. F., 1883, Bd. xx.) relates fifteen cases, of which six were treated at first by aspiration. Of these one died after a second aspiration. The others were treated by incision and drainage.

Goodhart (Guy's Hosp. Rep., 1877) reports two cases of aspiration, both of whom died.

œdema, and other accidents liable to occur when a lung, bound down by adhesions, is drawn upon by a powerful aspirating machine. These dangers are, of course, more rare in children, precisely because in them the lung is usually movable. The prejudice in favor of aspiration dates from the epoch when incisions were made without any antiseptic precautions. We now know that many of the dangers then attributed to the introduction of air were really due to infection of the wound or of the suppurating cavity. But it is again surprising how recent is this discovery, and indeed how long a time elapsed after the establishment of the Lister method elsewhere, before it was applied to the treatment of empyema: according to Bouveret,[1] the very first case in which pleurotomy was performed for empyema with antiseptic precautions occurred in Calcutta, under the care of an English surgeon, Ewart, and was reported by him in 1873.[2] In 1877, Goodhart speaks despairingly of the conflict of opinion in regard to the treatment of empyema; says that the incision treatment gives a mortality of 33 per cent., and is not more favorable than Playfair's method of subaqueous drainage. "This," he observes, "is simplicity itself, and looks, at first sight, almost perfect. I do not know that even now I am prepared to say that any other method of treating empyema is better, but, after treating several cases and seeing others treated, I think if no other treatment can be

[1] Traité de l'Empyème, 1888, Paris et Lyon.

[2] Lancet, 1873.

made to give better results than it, empyema will remain a most fatal disease, with the chances for or against the patient's life about even." [1]

In 1880, Dr. Cabot commented on the slow progress made by the antiseptic method in regard to the treatment of empyema, and attributed it in part to the tenacious belief of physicians that in aspiration they have a means of curing the patient with less risk, hence do not trouble themselves to master the methods by which incision may be stripped of its risks. At this date Dr. Cabot could find reports of but ten cases treated antiseptically, all in German; namely, four by Wagner,[2] four by Goeschel,[3] and two by Krabbel.

To-day, the cases of antiseptic pleurotomy have multiplied so considerably, that it would be useless to quote them in a paper like the present. I will again, therefore, simply refer to Dr. Holt's statistics of 63 cases, with 61 recoveries and 2 deaths. The statistics of Cabot and Eddison, reproduced in 1888 by Bouveret, of 40 cases of non-tuberculous empyema in adults, give 34 complete cures, 2 permanent fistulæ and 4 deaths.[4] The case which

[1] Loc. cit.

[2] Volkmann's klinische Sammlung, No. 197. Also Berlin. klin. Wochen., 1878.

[3] Berlin. klin. Wochen., 1878.

[4] Among reported cases of successful pleurotomy may be cited:
Goeschel: Loc. cit., four cases, four recoveries (young children).

Phelps (N. Y. Record, 1880): fourteen mixed cases, eleven recoveries, three deaths.

forms the basis of this paper is the sixth I have treated, and with success. My friend Dr. Annie Daniel also reports six cases where antiseptic drainage treatment was followed by complete recovery. There can be no doubt, therefore, that the pendulum of chances has swung over so considerably during the last decade, that, with incision and drainage treatment, recovery of children from empyema should be considered the rule—death the exception.

There are, however, four details of the treatment that are not so well settled. These are, the use of the spray, the size of the opening to be made in the chest wall, if puncture and aspiration be excluded; the employment of irrigations, and the use of a valve in the dressing. When, in 1873, far away in Calcutta, the antiseptic method was, as it would appear, first applied to the empyema operation, the incision and subsequent dressings were rigorously guarded by the spray. For a long time the spray was considered indispensable; and as late as 1888, Bouveret, while admitting the superfluity of the spray for other surgical operations, insists upon re-

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Lindner: Jahrb. für kinderkrank., N. F., Bd. xvii., one case recovered—seven months' child.

Skerritt (Brit. Med. Journ., 1876): one case, recovered.

Cabot (N. Y. Med. Journ., 1880): seven cases, children, all recovered rapidly.

Redenbacher (Deutsch. Archiv. für klin. Medicin, Bd. ix.): one case, recovery in fourteen days.

Huber (Archives of Pædiatrics, Nov. 1889): two cases, double empyema, recovery.

taining it in treatment of empyema. The spray was used by Skerritt[1] in 1876, by Koenig and Wagner in 1878,[2] but the latter does not consider it necessary, and the former claims always to resect a rib. The spray is uniformly advised by Douglas Powell,[3] and by Bennett in Ashhurst's *Cyclopædia of Surgery*. It was strenuously insisted upon by Dr. Cabot in 1880,[4] by Leamoine in 1880, and is advised by Donaldson, writing in Pepper's *System of Medicine*, whenever an incision is made six centimetres long. It is considered superfluous if the incision only passes through the skin and muscles, and the pleura itself is opened by a trocar. In the Academy discussion of 1887, Dr. Abbe advised the spray, but this was not mentioned by any other speaker, nor in the discussion at Washington last September over Dr. Huber's two remarkable cases of double empyema. Dr. Gerster, in his treatise on antiseptic surgery, expressly condemns the spray as an objectionable feature for empyema as for other operations.

In the case of the little boy here described, no spray was used, and recovery was complete—*i. e.*, the tube was withdrawn on the thirty-second day. In my five other cases, however, the duration of

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[1] Brit. Med. Journ., 1876.

[2] Berliner klin. Wochensch., 1878.

[3] Diseases of Lungs and Pleura.

[4] N. Y. Med. Journ., 1880. See also Neurbe-Fraentzel, in Ziemssen.

The spray was used in all the forty-one cases, including fourteen cases of children, in the statistics compiled by Bouveret.

treatment was about two months. In Dr. Daniel's six cases the spray was also omitted, but other antiseptic precautions were used. The trocar and drainage-tube employed had been kept in pure carbolic acid during the twenty-four hours preceding the operation.

Of these six cases one died suddenly on the third day, twenty-four hours after an erysipelatous inflammation around the wound had been noted. In the five other cases the tube was removed on the thirteenth, nineteenth, twenty-third, twenty-eighth, and thirty-third days respectively.

While the fluid is running out from the incised chest no air can enter. The entrance of air is signalized by a loud suction noise, and takes place at the moment that the abnormal positive tension in the pleural cavity, due to the presence of the fluid, is changed to a negative tension by its evacuation. It is quite possible, if the contents be perfectly fluid, to place a thick layer of antiseptic gauze over the opening at the moment the flow begins to slacken. By this means any air drawn into the chest will be filtered. This would even be possible when, through a large opening, semi-solid masses of fibrin and clots were being being expelled by coughing.

It is generally admitted now that infection of wounds does not proceed from germs floating in the air, but attached to instruments and other solid bodies. Further, the experiments of Stimson, confirmed by Cabot himself, who so strenuously recommends the spray, show that air which has passed through spray continues to infect culture tubes ; on

the other hand, methods of operation which effectually exclude air, as the subaqueous drainage, and the guarded trocar of Reybaud, were very often followed by fever and other signs of sepsis, often fatal. On one day when I operated by the trocar on a child at the Mount Sinai Dispensary, another child of the same age was admitted to the wards and submitted to subaqueous drainage. The dispensary case, though brought from a distance three times a week, recovered, after some vicissitudes, in two months. The hospital case died of exhaustion after three.

In cases where air has been thoroughly excluded from the pleura opportunity remains for infection of the external wound; and this opportunity recurs with every change of the dressings. Constant irrigation of the lips of the wound during the dressing is a much more potent method of averting infection than is the spray.

The size of the incision seems to have been regulated according as the operators were more preoccupied with freeing the pleural cavity from pus, or with facilitating the reëxpansion of the collapsed lung. It is under the influence of the first idea that König and Demme have advised the resection of a rib for, at least, all adult cases; that directions are given for incisions six centimetres long, and that stress is laid upon placing the incision as low as possible. Certainly, for children at least, too many cases are now on record of cure by simple incision to allow us to consider resection as anything but an exceptional expedient. Further, so long as the contents of the pleura are entirely fluid, it is difficult to

see why they will be evacuated any more easily through an opening of six centimetres than through a tube the thickness of a finger. The tube is only inadequate if there are solid coagula too large to pass easily through it. Similarly, it seems to me extremely doubtful whether the situation of the tube at a lower portion of the chest is more favorable to the outflow than a higher position. In a case of empyema that I saw in consultation with Dr. Daniel, the pointing was under the right clavicle, and here the opening was made. Drainage was perfect; and this is always the experience with spontaneous openings of empyema. The fact that these openings occur in the upper parts of the chest at least as often as lower down, is itself a proof that the contents of the pleural cavity may be pushed toward any point on the circumference, and do not follow the laws of gravity. The familiar experience of the straight glass drainage-tube which is so often plunged into the peritoneal cavity after laparotomy operations, shows that the pressure of the closed cavities of the living body is capable of forcing fluids upward as well as downward. In the empyema operations the perforated drainage-tube generally passes upward; it certainly did so in the case of Frank. But the circumstance did in nowise interfere with the drainage.

The forces which expel the fluid from the pleura are: 1. The positive tension existing in the cavity, and which, to the great detriment of the patient, has replaced the negative tension which is normal. 2. The reëxpansion of the lung, which should begin as

soon as this positive tension is lessened. This is illustrated in the balloon and flask. 3. The respiratory movements—those of inspiration as well as those of expiration. During inspiration, when the chest-wall moves outward and enlarges the pleural cavity, all the contents of the cavity must move forward in the direction of the least resistance. Unless the opening be occluded, the lung will not so move, because the internal atmospheric pressure which should keep out the walls of its cavities, is neutralized by air on the other side, and is, therefore, inoperative. But if there be fluid in the cavity, its pressure exceeds both that of the air within and of the air without; and when compelled to move, it moves forward toward the point of least resistance—*i. e.*, the fistulous opening toward the external air.

For these reasons it is difficult to see any advantage in a very large opening; provided, of course, that the flow of liquid continues perfectly unobstructed.

The gradual contraction of the pus cavity, effected through the approximation of the pleural surfaces, can hardly be counted among the expelling forces. Certainly a most important condition for the formation of such adhesion is the persistent evacuation of the pus as fast as it forms. In the case of Frank, as the flow of pus through the canula began to slacken, an antiseptic pad was laid over the opening—not, however, before air was twice drawn into the pleura with the usual suction noise. The respiration was considerably accelerated at the moment of opening the pleura, and for some moments afterward, the

inspiration becoming deeper. The same change in respirations is observed when a closed tube, communicating only with a manometer, is plunged into the healthy pleura of a dog. The change seems due entirely to the greater exertions made by the sound lung, but implies a direct transmission of impressions from the wounded pleura to the inspiratory centre in the medulla.

In the boy Frank the opening made by the trocar was enlarged by the bistoury until it would easily admit the drainage-tube; this was inserted, and secured by a safety-pin packed around with iodoform gauze, after the lips of the wound had been thickly powdered with iodoform, and while the pus was still running from the tube, an antiseptic dressing was applied without previous irrigation of the pleural cavity.

The question of irrigations into the pus cavity—primary or consecutive—has been strenuously debated. When advised, it is with the intention: 1. Of thoroughly removing all pus from the pleura, so that none may remain to decompose. 2. Of disinfecting the pleural cavity of germs which, in spite of all previous precautions, may have been carried into it.

Now this second reason can have no weight, if the antiseptic precautions previously taken have any real efficiency. As to the first reason, the records of cases prove that pus reaccumulates in the twenty-four or forty-eight hours following the operation in amount sufficient to necessitate a change of the dressings, and this, whether irrigation has been

practised or not. Nevertheless, many of the writers who use primary irrigation, as Cabot, do not repeat the washing on account of this reaccumulation, but simply renew the dressings. If the irrigation be not needed the second time, it is difficult to see why, for the purpose of removing the pus, it should be required the first time.

The amount of pus that is poured out in the first day or two after the operation is often astonishing. In the case of Frank—where, at the first dressing, thick layers of cotton wool were used instead of, as subsequently, oakum—the dressing, clothes and even bedding were saturated. It is true the evacuation of pus had not been quite complete at the operation; but there could not have been much fluid in the pleura, for, before applying the dressing, I ascertained that almost normal percussion resonance extended all over the back of the chest. The abundant discharge, therefore, of the first day must have been due to a new formation or effusion of pus; and it is comprehensible that the removal of pressure from the pleural surfaces may facilitate an abundant emigration of leucocytes from the distended capillaries and lymph spaces of the pleural tissue.

In a perfectly normal progress of events, when the later or secondary elimination has been effected, the discharge from the drainage-tube should rapidly diminish and cease. Bouveret relates one case of complete cure in nine days, the shortest on record. Many cases are on record where the tube could be removed in twenty or fifteen days, or even less. In Ewart's pioneer case, an adult, the discharge

is said to have become serous in six days. Two circumstances thwart this normal progress: the suppurating surface may become infected, or the pleural inflammation which gave rise to the suppuration may persist as suppurative, instead of retrograding to an adhesive form. In either case, the child will have fever, and the discharge will remain offensive. In either case, irrigation becomes indicated, and, if practised, will be followed by a fall of temperature.

It is certain that thousands of irrigations have been practised which only serve to keep up the irritation they were intended to allay. This is especially the case with carbolic acid irrigation, of either one, two, or three per cent. The danger of poisoning is very considerable; but, apart from that, the danger of irritating the inflamed tissue of the pleura is more uniformly present. Cases treated by carbolic acid irrigation have been described complacently as sustaining a treatment of three months, which, in a non-complicated case, itself impugns the treatment. In two of my own cases, one per cent. solution of carbolic acid was used for irrigation when the temperature rose; but the child became restless, as from pain, and the temperature rose higher. Irrigation with a solution of bichloride 1 : 6000 was substituted, and the temperature fell, not again to rise.

Out of the five cases reported by Dr. Daniel only one was irrigated. The irrigation was made daily with a two per cent. solution of carbolic acid, for a period of nineteen days, yet the fever continued

with little abatement. It is evident that, apart from the irritation of the inflamed pleura, repeated irrigations tend to thwart the two essential parts of the healing process. Each tends to break down the delicate adhesions forming between the pleura, and to oppose the reëxpansion of the lung. No one can deny their utility when pus is found fœtid at the time of the operation, or if it become so afterward, for it is important to remove fetid pus or gangrenous masses at once, and not trust to their gradual elimination. But there is no proof that it is important to remove fluid and laudable pus at once, but only to provide for its free, steady, and uninterrupted gradual evacuation. As soon as the internal tension of the pleural cavity has been relieved by removal of such excess of fluid as spurts with force through the drainage-tube, and as soon as drainage is instituted and maintained, tendencies to absorption of pus are arrested and the lung is enabled to reëxpand. If the pleural cavity were empty of fluid, but, from imperfect collapse of its walls, filled with air at ordinary atmospheric pressure, expansion of the lung would be retarded as much as in the presence of fluid. This is sufficiently demonstrated by the accident of pneumothorax. There is really no advantage in removing the pus faster than the lung can follow its retreat, and the contact of the pleural surfaces be effected.

In my case, no irrigation was made at the time of the operation. The next day, the rectal temperature, which had been 104° on the afternoon of the operation, had fallen to normal; the dressings were

saturated, and were removed. During removal, air was twice, but only twice, sucked into the pleura. During the next week I did not see the child, but the dressings were changed every two days by another physician. The temperature, taken in the mouth, was reported as normal during the week, but the cough was severe, while it had been scarcely perceptible before. On the seventh day I saw the child again, and found the rectal temperature 101½°. The percussion resonance over the lung was nearly normal, the breath sounds harsh and bronchial without vesicular murmur; the heart was in place. In changing the dressing this time, the cotton wool outside the antiseptic gauze was replaced by oakum. Before replacing the dressing, air was again drawn into the chest with a loud noise. Again I did not see the child for four days, during which, however, the dressing was twice changed by the other physician. On the eleventh day after the operation, I found the rectal temperature 103°, the child coughing much, still pale and languid, complaining much of pain in the chest. On this occasion, and for the first time, I irrigated from a fountain syringe with a warm solution of corrosive sublimate, containing 1 : 6000. On this occasion, no air was drawn into the chest. Two other changes were also made in the treatment: a valve of rubber tissue, hitherto imperfectly applied, was accurately adjusted over the fistula, and antipyrin was given in five-grain doses every three hours. Three effects were observed: The temperature fell permanently after seven doses of the antipyrin had been taken. The discharge lessened

so much that the dressing remained untouched for a week, and was then found scarcely soiled. The cough lessened, the child became lively and free from pain, and a week after the irrigation, eighteen days after the operation, was found running about, eating well, and appearing quite well. The dressing was replaced, left a week longer, when the fistula was found to be granulating abundantly, the discharge entirely trivial. It is possible that the tube might then have been removed ; it was evident that the pleural cavity had contracted to a sinus around the tube. For greater security, the tube was simply shortened, and only entirely removed a week later, on the thirty-second day after the operation. The fistula closed immediately.

On the eleventh day, when irrigation was performed, the character of the discharge had changed—become slightly sanious, with a few small fibrinous coagula. But there was no evidence of their decomposition, nor of septic infection of the wound, although on several occasions the dressings had been too loosely applied, and the antisepsis imperfect. The fever, pain, and cough seemed to have been kept up by the continued inflammation of the pleura, and it is this which seemed to subside promptly under the combined influence of the bichloride irrigation, the valve, and the antipyrin.

The use of a valve in the dressing of the empyemic fistula has received much less attention than it deserves. The elaborate valvular apparatus de-

scribed by Phelps, in 1880,[1] does not seem to have been employed by any one else. It necessitates a double opening in the chest, and is otherwise too complicated for general use. When a valve of *baudruche* was used around the trocar, in the French method of operating which preceded the antiseptic, no arrangement was made for keeping up a valve action by the dressings. Dr. Cabot, in his paper of 1880, is the first writer I know of who has perceived the desirability of a valve. He recommends, however, to utilize the mackintosh of the Lister dressing for this purpose, allowing it to overlap the gauze upon the skin, instead of, as is usual, falling short of the dimensions of the gauze. It seemed to me that this same idea could be more effectively carried out by placing a piece of rubber tissue, the size of my palm, directly over the opening, upon the skin and under the dressing. The piece of rubber was, of course, previously soaked in a bichloride solution. After the conclusion of my case, I found that Bouveret has advised a similar valve to be placed directly over the fistula, but this to be attached to the upper border by collodion, and left free below. My thin layer of rubber tissue, as soon as it was *in situ*, became closely applied to the skin by atmospheric pressure.

On the first dressing a valve had been imperfectly applied, and continued to be so until the eleventh day. Up to this time air was always drawn into the lung as soon as the dressing was removed. On

[1] New York Med. Record, 1880.

the eleventh day a better valve was made of thin rubber tissue, and a week later, when the discharge had almost entirely ceased, no air was drawn into the chest when the valve and dressings were removed.

It might at first sight appear as if a piece of rubber, closely applied over the opening as above described, would interfere with the discharge of pus through the drain. The discharge is, however, effected during expiration, when the intra-pleural pressure becomes superior to the pressure of the external air against the valve, and, therefore, raises it sufficiently for fluids to trickle out.

Peyrot[1] has shown that in pleural effusions the type of expiration changes; the force of inspiration diminishes as the expansion of the chest becomes incapable of determining a vacuum, and expiration becomes the principal act. It becomes active instead of passive, as is normal, and may be decomposed into two periods. In the first the glottis remains closed, and air is pushed toward the depths of the bronchi. In the second period the glottis opens, and air is expelled with a sigh. This form of respiration is normal to birds. It also greatly resembles that of frogs, where the lungs are not contained in closed cavities, and where, therefore, there is no mechanism for aspiring air by the creation of a potential vacuum. While the glottis is open air enters the upper air-passages. The glottis is then closed, and air is jerked toward the termini

[1] Archives Gén. de Médecine, 1876.

of the bronchi by movements resembling those of deglutition.

Plate III

This change of respiratory type is well shown on some respiratory tracings taken from the right side of a dog's chest during successive injections of plaster-of-Paris into the left pleural cavity. The expiration begins to be prolonged and divided into two phases during the third injection, and from that moment the inspiration continues to diminish in amplitude and duration—the expiration to increase in both.

Plate IV

In another dog, where a carotid tracing was taken during the injection, the trace immediately showed an increase in the respiratory oscillations, and a rise of blood-pressure to the extent of five millimetres of mercury. After the fifth injection there was a second rise of blood-pressure to the extent of ten millimetres. When twelve ounces of plaster-of-Paris had been injected, the pulsations were arrested, and the manometer needle fell fifteen millimetres.

The change of respiratory type in pleural effusions is not due to pressure exerted on the lungs, but to the inadequacy of the inspiratory expansion to effect its purpose of drawing air into the lung. This inadequacy persists after evacuation of the fluid and establishment of a fistula, although the abnormal positive intra-pleural tension be then greatly diminished. Therefore, the new type of breathing persists, though to a less degree. It would be very interesting to demonstrate this upon the human subject, but I have not been able to do so.

It is easy to see that the change of type is an ad-

vantage in the double task imposed—that of expelling fluids from the chest, which must be effected during expiration, and of reducing to a minimum the aspiration of air into the pleura, which would be effected during a vigorous inspiration. Correlatively with these desiderata, which inverts the normal ones, we find experimentally, and shall probably find clinically when we look for it, that the normal force of the respiratory movements is inverted—inspiration is diminished and expiration is increased.

The immobilization of the chest walls on the affected side while an intra-pleural effusion exists, and their collapse—especially marked in children after the fluid is evacuated—seem to be the mechanism by which inspiration is diminished. The cough, which, as in our case, comes on or is aggravated after the operation, is one of the means by which expulsive expirations are increased.

With these favoring circumstances, even the ordinary Lister dressing often suffices to solve the problem of so greatly diminishing the entrance of air through the fistula, that the air remaining within the pleura may become rarefied, the lung submitted to unopposed atmospheric pressure, and, therefore, reëxpanded. This is the true mechanism of the clinical phenomenon which Dr. O'Dwyer has recently discussed with a certain despair of finding the explanation. Although air be not absolutely excluded from the pleura, yet if it be not renewed, or renewed in less proportion than it is absorbed, it will soon become rarefied, and the conditions of

pulmonary reëxpansion are then established as positively, though less vigorously, than when a complete vacuum exists.

Homolle[1] has contrived to measure intra-pleural tensions by means of a manometer attached by a lateral stop-cock to the trocar used in evacuating effusions. In a case of empyema the measurements varied thus:

Before any fluid was withdrawn the intra-pleural pressure was positive, and equivalent to ten millimetres of mercury. When 500 grammes had been withdrawn, it had sunk to 0.002 millimetre; when 900 grammes, the pressure became negative to the extent of 0.007 millimetre, and after withdrawing 1000 grammes, the negaive pressure was eighteen millimetres.

In the dog in whose pleura I injected water through an air-tight canula communicating with a manometer, the pressure was negative to the amount of five millimetres, and remained so after 300 grammes of water had been injected.

These facts show that the pleural cavity may contain some air and some fluid, and yet remain in a state of negative pressure relative to the atmospheric air, which, therefore, should not be opposed in expanding the lung.

As Weissberger has further pointed out, during the process of adhesion and obliteration of the pleural cavity the lung becomes tugged forward piece by piece, and when the adhesions are com-

[1] Revue Universelle Médecine et Chirurgie, 1879.

plete, the lung must be drawn out by every expansion of the thorax.

The presence of fluid in the chest when there is a free opening for it to run out, offers little more obstacle to the reëxpansion of the lung than does the pressure of fluid in the flask to the reëxpansion of the balloon. This is because the pressure of the fluid is always superior to that of the external air, and therefore easily overcomes it.

It is the clinical observation of frequent and even speedy recovery with the use of the Lister dressing alone,[1] which demonstrated that the above processes must take place as described.

But whatever beneficial influence, from the dynamic point of view, may be exercised by the Lister dressing, is certainly greatly intensified by the use of such a valve as I have described. I think there is no doubt that the cavity became contracted to a sinus on the fifteenth day after the operation, and that the tube might have been removed at least ten days earlier than it was.

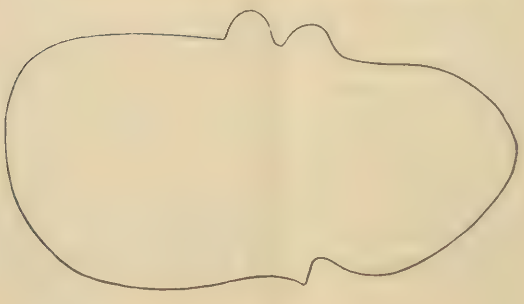
To the extent to which the occlusion of the fistula during inspirations is complete, the normal type of respiration tends to be reproduced, and the cavity to be obliterated by more vigorous inspiration of the lung.

Peyrot remarks that when, being bound by false membranes, the lung is unable to expand, the

[1] In one case reported by Bouveret, the empyema was completely cured in nine days, the shortest time on record. The expansion of the lung was so rapid that it certainly preceded the cicatrization of the pleura.

diminution of pressure in the pleura seems to favor putrefaction or fermentation, even without contact with external air. The importance of the pulmonary expansion as a means of obliterating the cavity is so great, and as such has always been so

CAST I.



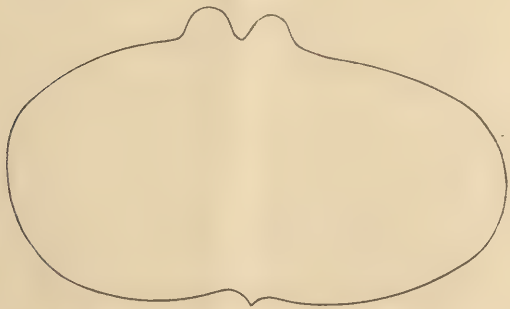
In profile.

well recognized, that the frequent failures of such methods as subaqueous drainage[1] seem more surprising than its successes. These failures are the

[1] Playfair: Transactions London Obstetrical Society, 1872.

best possible proof that the antiseptic part of the problem is as important as the mechanical; that sepsis is liable to occur through infection of the external wound, even when air is rigorously excluded from the pleura; and finally, that constant irrigation of granulation tissue that should be left in the greatest repose, interferes both with the healing and with the mechanical mechanisms of reëxpansion. During the treatment of the boy Frank, I took a certain number of casts of his chest, by a process which is very simple, but which I have not hitherto seen described. I encircled the thorax with a cytometer, and having carefully removed the instrument I placed it, closed, on a perfectly flat surface, and

CAST II.

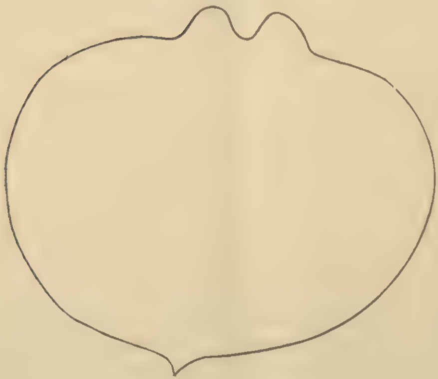


poured in fluid plaster-of-Paris. A cast was thus obtained, one-half an inch in thickness, and which accurately represented a transverse segment of the chest, and the inequalities of the two sides. The first cast was taken on the eighteenth day, a week

after the irrigation. It represents a segment immediately under the axillæ. The second cast is from

CAST III.

CAST IV.



the same locality, and is taken a week later, the twenty-fifth day. The two other casts were taken

a few days after cicatrization. No. III. from the level of the axillæ, No. IV. from the level of the seventh rib. The odd-looking projections on the posterior aspects of these casts are due to a mistake made in the application of the cytometer, which was put on inside out. This does not, however, essentially change the character of the casts.

The general shape of the affected side in the fourth cast well illustrates Peyrot's remark, that there is a total deformity of the chest, which results in a sort of "oblique oval thorax." I regret very much not to have secured a cast on the preceding week, as then the affected side was much more col-

Casts superimposed.

lapsed, the shoulder drawn over and downward, so that the alarmed parents inquired about the danger of permanent deformity. The cast of the eighteenth day shows: First, a deviation of the sternum

toward the affected side, and half an inch to the left of an antero-posterior line traversing the segment from the vertebral column. Second, a marked diminution in circumference, in transverse and in antero-posterior diameters as compared with the sound side.[1] The cast taken the following week, however, shows that the differentiation on the first occasion had depended upon an enlargement of the right half of the chest, as well as on the contraction of the left. The deviation of the sternum was much less; and the right circumference both to the deviation and to the median line was two inches less than it had been before the transverse diameter was diminished an inch; the antero-posterior the least of all—a quarter of an inch.[2] The measure-

[1] Measurements, October 14th:

	Inches.
Circumference, left (affected side), to point of deviation of sternum	7½
Circumference, right, to point of deviation of sternum	10½
Circumference to median line, left	8¼
Circumference to median line, right	10
Transverse diameter to median line, left	3¼
Transverse diameter to median line, right	4¼
Antero-posterior diameter, left	3
Antero-posterior diameter, right	4

[2] Measurements, October 22d:

Circumference to deviation, left	9¼
Circumference to deviation, right	8½
Circumference to median line, left	9½
Circumference to median line, right	8
Transverse diameter, left	4¼
Transverse diameter, right	3¼
Antero posterior diameter, left	3½
Antero-posterior diameter, right	3¾

ments of the left side are increased, not only over those of the previous week, but over those of the right side, except the antero-posterior diameter, which is still one-quarter inch smaller. As before, the transverse diameter exceeds the antero-posterior.

In the following week, after cicatrization of the fistula, the sternum has returned to the median line, the diameters of the two sides of the chest are nearly the same, but the right circumference exceeds the left by one and a half inches. Below, at the level of the xiphoid cartilage, the circumferences are equal; to the median line, both diameters larger on the right side by one-quarter inch.[1]

It is interesting to be able to measure thus graphically the compensatory hypertrophy and shifting of the sternum and mediastinum during the collapse of the left lung, and the gradual diminution of this

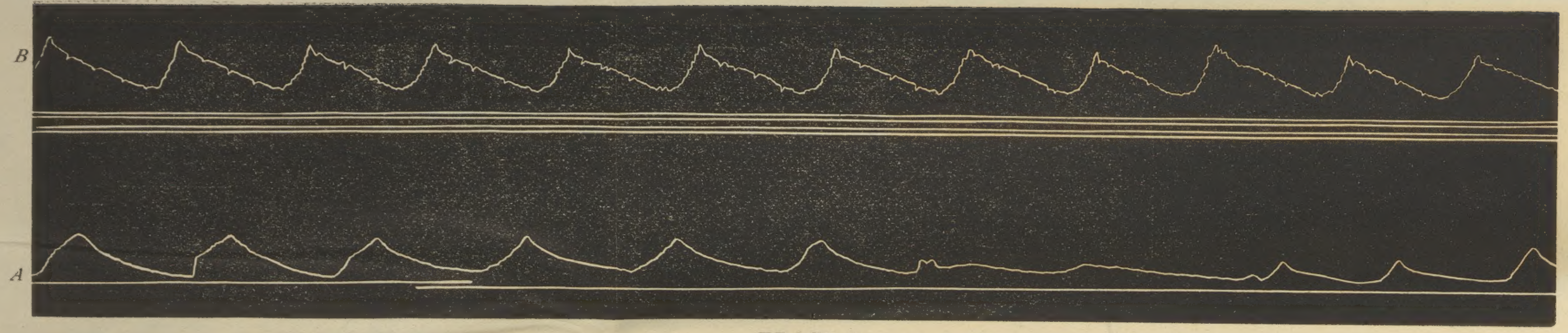
[1] Measurements, November 2d, under axillæ:

	Inches.
Circumference, left	8½
Circumference, right	9½
Transverse diameter, left	3½
Transverse diameter, right	3½
Antero-posterior diameter, left	4
Antero-posterior diameter, right	4¼
At level of seventh rib and xiphoid cartilage—cartilage deviated to right:	
Circumference to median line, left	8¼
Circumference to median line, right	9½
Circumference to deviation, left	8½
Circumference to deviation, right	8½
Transverse diameter, left	3¼
Transverse diameter, right	3½
Antero-posterior diameter, left	4¼
Antero-posterior diameter, right	4½

hypertrophy and restoration of normal proportions as the collapsed lung expanded.

In concluding this paper, which has not aimed at being systematic, but which has taken up details of interest as they occurred to me, there is one further remark to make. It seems to me that the two common observations of the frequency of empyema in children, and of its usually favorable course, are observations mutually correlative. The favorable prognosis does not apply to the empyemas of infectious diseases; nor is it solely due to the greater elasticity of the chest walls in childhood, permitting more facile collapse. But the appearance of pus in the effusion is to be considered less significant, because more easily excited by the same degree of inflammation. It would seem as if the rich system of subendothelial lymphatics in the pleura,[1] poured out leucocytes freely through the intercellular stomata, when these are dilated in the inflammatory hyperæmia of the pleura, and during the preliminary shrinkage of the endothelial cells.[2] Pus, therefore, appears in the effusion before the pleura has became thoroughly infiltrated, and continues to be secreted so long as the stasis remains in the vascular and lymphatic capillaries.

[1] Klein: Anatomy of the Lymphatic System.
[2] Delafield: Studies in Pathological Anatomy.



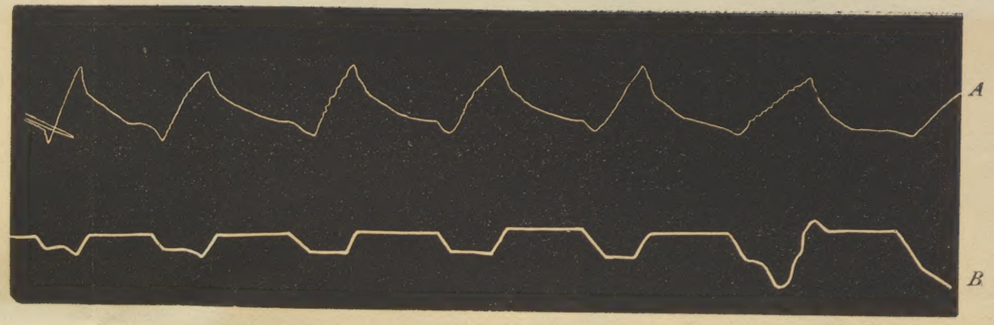
TRACE I.

Traces taken with a Marey Tambour on Right Side of Chest. The Glass Tube Plunged into Left Pleura.

A. Normal respiratory trace. Eleven respiratory movements in unit of time.

B. Respiratory tracing from right side of chest, taken immediately after plunging one arm of glass T tube into left pleural cavity. The inspiration is amplified, slightly accelerated twelve respirations in unit of time.

p. 6



TRACE II.

Taken after 150 Cubic Centimetres of Water had been Injected into Left Pleura.

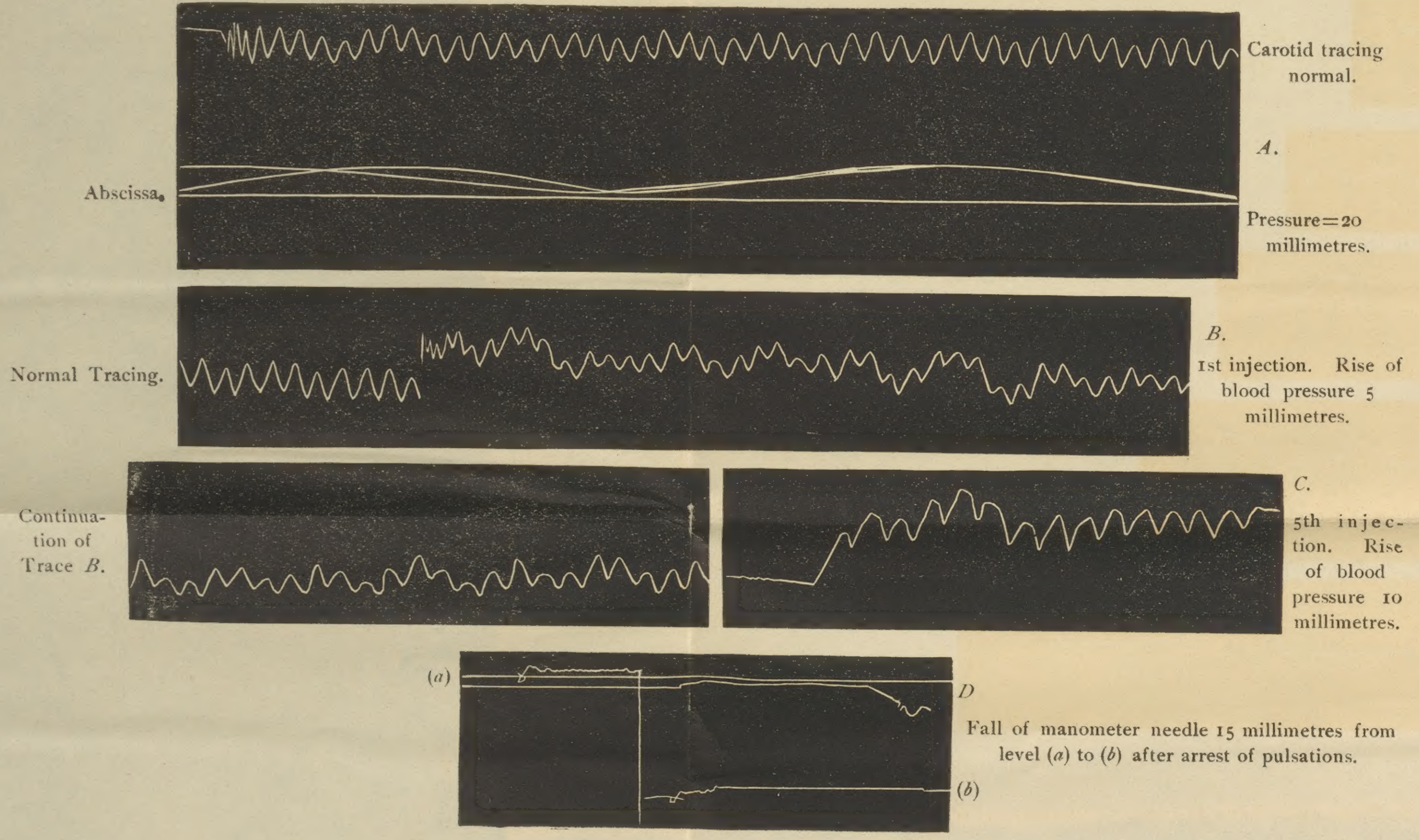
A. Respiratory trace still further amplified.

B. Tracing by a needle of a manometer which was connected with left pleural cavity by means of the T tube through which the injections had been made. Needle falls during inspiration, rises with expiration; mercury rose five millimeters in proximal limb of manometer showing persistence of negative pressure in pleura in spite of injection.

p. 7

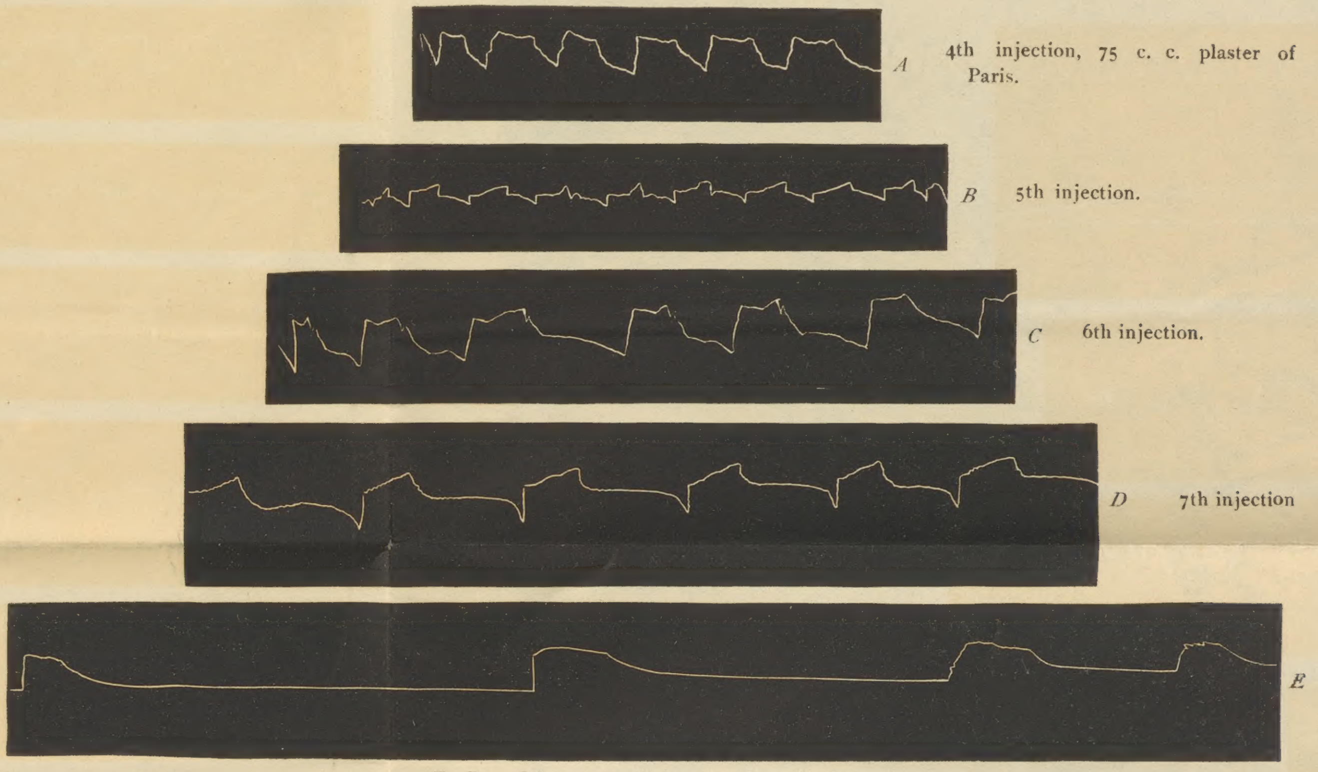
p. 40

p. 38



TRACE IV.

p. 38



E. Convulsive gasps after arrest of respiration.

TRACE III.

Shows Change in Respiratory Type during Successive Injections of Plaster of Paris into Left Pleura. Tambour placed on Right Side of Thorax

In these traces, ascending lines mark inspiration, descending lines mark expiration. Inspiration takes place in two times, marked by a vertical ascending line, followed by an oblique ascending line. The expiratory trace is also composed of an abrupt descending line followed by an oblique descent. The peculiarities are most marked in trace *D*.